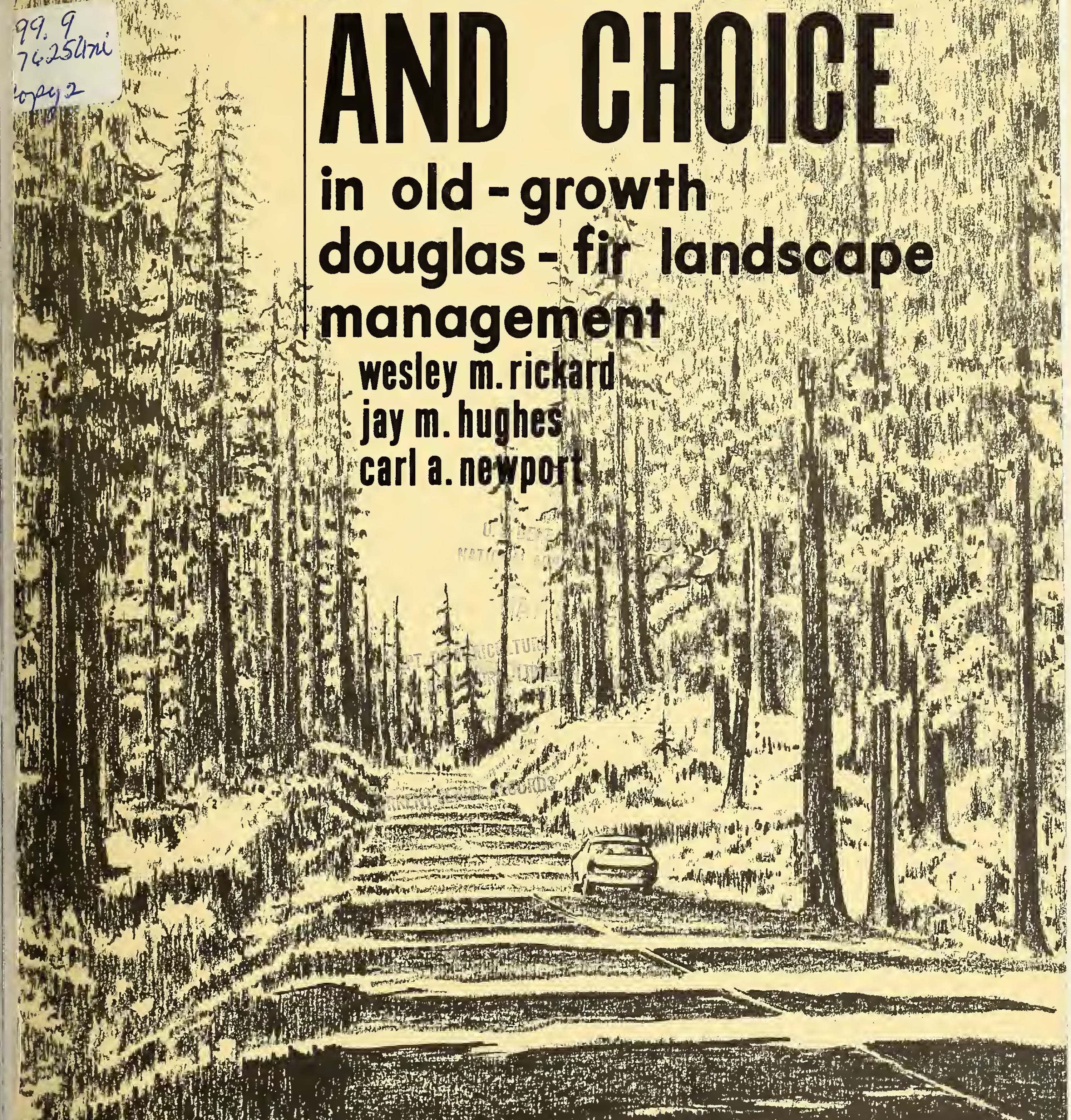
ECONOMIC EVALUATION AND CHOICE

in old-growth douglas-fir landscape management

wesley m. rickard
jay m. hughes
carl a. newport



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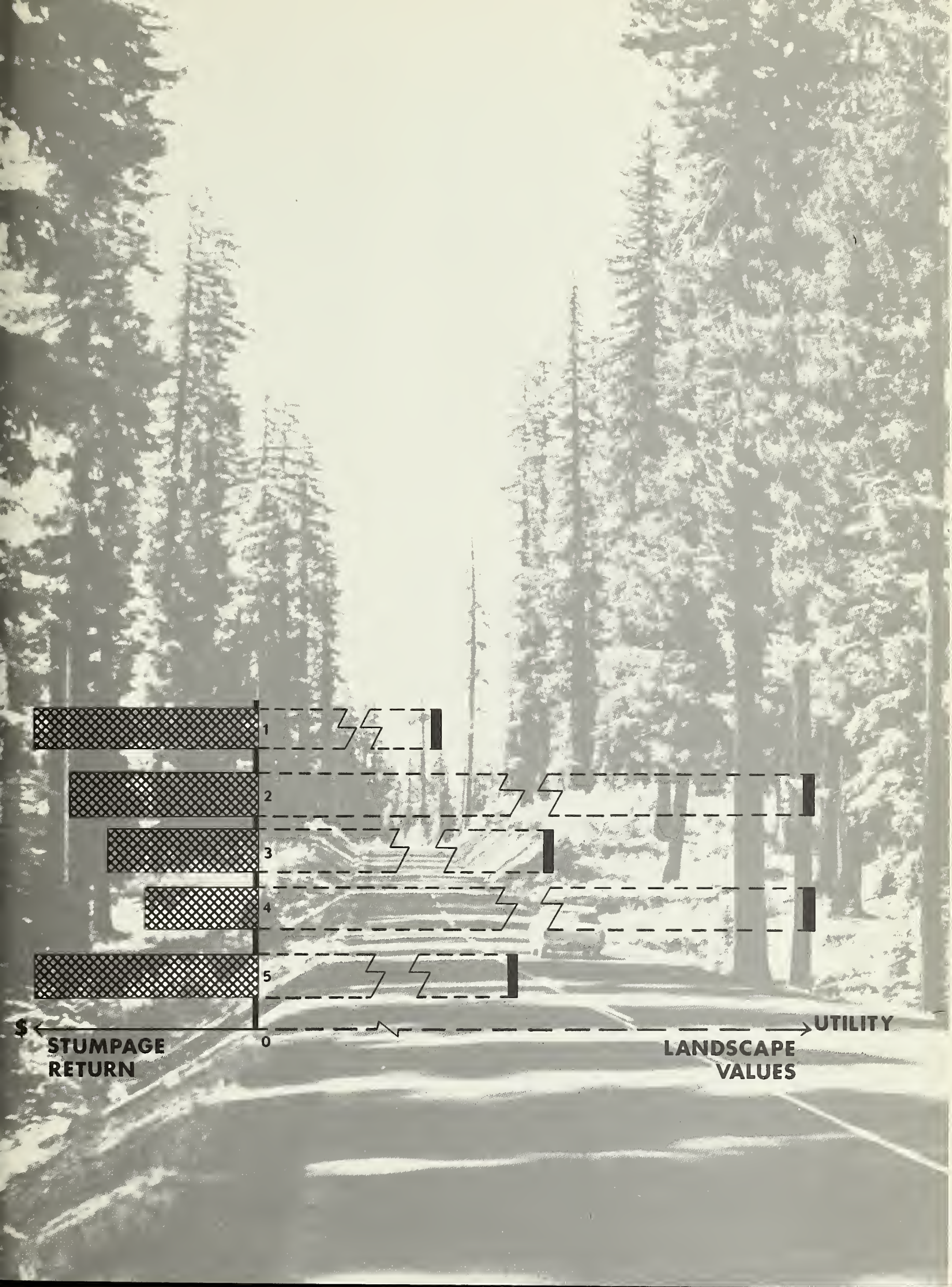
The authors conducted this study during 1961 to 1965 while employed by the Pacific Northwest Forest and Range Experiment Station in Portland, Oregon.

Wesley M. Rickard is currently a forest management, policy, and economics consultant in Tacoma, Washington.

Jay M. Hughes is an associate professor in the School of Forestry at the University of Minnesota, St. Paul, Minnesota.

Carl A. Newport is a partner in the consulting forestry firm of Mason, Bruce, and Girard in Portland, Oregon.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Introduction

The Problem and Its Setting

One problem facing forest managers in the Pacific Northwest is framed by the question: How shall timber be cut, not only to produce wood but also to maintain or enhance scenic beauty or the esthetic yield of the timber stand and the forest landscape? This problem arises because timber production and esthetic yield sometimes conflict. It is an important problem because policies and programs of timber owners frequently require the timberland manager to consider both economic and esthetic yields where conflicts between cutting and beauty occur. Thus far, there are few guides to help the timberland manager choose that cutting method which best combines esthetic and economic yield.

Figure 1.–A stand of old-growth Douglas-fir.

The Douglas-fir subregion of the Pacific Northwest[1] is one area where this problem occurs. About 8 million acres of commercial forest land in this subregion are stocked with stands 100 years old and older. These stands contain the larger trees generally considered to be more desirable from an esthetic point of view. Over 1.8 million acres are in stands 300 years old and older (fig. 1). About half of this acreage is on National Forests with the balance split mainly between large private owners and other Federal ownerships (U. S. Forest Service 1963).[2]

In addition to 367 billion board feet, International 1/4-inch rule,[3] of Douglas-fir sawtimber, the Douglas-fir subregion contains many scenic attractions (figs. 2 and 3) and hundreds of miles of highways and roads serving the traveler to and through the forests (fig. 4). The timber of the Douglas-fir subregion thus has utility, not only for wood products but also as a scenic backdrop for recreation and other activities. Harvesting the timber for its wood products may mean forgoing the harvest of scenic values.

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[1] This is generally regarded as that timberland west of the Cascade Range in Oregon and Washington. Approximately 55 percent of the volume of softwood trees 11.0 inches d.b.h. and larger in this subregion is in the Douglas-fir species.

[2] Names and dates in parentheses refer to Literature Cited, p. 33.

[3] Unless otherwise mentioned, board-foot volumes are in terms of Scribner rule.

Figure 2.--Mount Baker reflected in Baker Lake in Washington.

Figure 3.--Mount Hood rises above the forest landscape adjacent to a forest road in Oregon.

Figure 4.–Old-growth Douglas-fir enfolds this forest road on the Umpqua National Forest in Oregon.

Purpose and Scope of Study

This paper presents, by example and explicit calculation, some economic consequences of alternative kinds of timber cutting where esthetics are involved. Several timber cutting alternatives are simulated in order to bracket the intensities likely to be proposed by forest managers. The calculations illustrate a method of measuring some of the economic consequences of timber cutting alternatives and also provide at least a partial guide for ranking alternatives.

Further, this paper describes the decision-making problem that arises when the forest-land manager must choose among actions having both dollar and nondollar consequences.

This discussion is limited to old-growth[4] Douglas-fir, although the methods are applicable to other species types and stand ages. It is limited further in scope to an acre-by-acre or stand-by-stand point of view as opposed to a more aggregative approach. Any economic effects on the balance of the timber planning area were ignored.

[4] "Old growth" is used in this study to connote timber generally more than 100 years old, and not necessarily "virgin," "mature," or "overmature." The "old-growth" data used in this study conform with net volumes and yields for Douglas-fir timber over 100 years of age in the publications by McArdle (1961) and Staebler (1955).

The economic analysis concerns mainly calculating discounted present values of estimated current and future stumpage returns from selected timber cutting alternatives. It is not concerned with the impacts of the selected timber cutting alternatives on allowable cuts or rotation lengths. These must be the subjects of future research.

Some general principles of landscape design and esthetics are briefly considered as well.

Finally, suggestions are offered for viewing jointly the dollar and nondollar consequences of the timber cutting alternatives. In these suggestions, the method and not the data is emphasized.

The Timber Stand and Cutting Alternatives

The silvical nature of old-growth Douglas-fir stands is almost as complex and varied as the needs of people who seek opportunities for recreation in them. Stand age may vary from 100 to over 600 years. Old-growth stands occupy all site productivity classes, and gross volumes per acre can range from well under 100,000 to over 300,000 board feet. Although Douglas-fir trees dominate the oldest stands, the more tolerant associated species, such as the true firs, hemlocks, and cedars, generally make up a large portion of the inventory. The Douglas-fir stand is a subclimax type of forest that depends on such influences as fire, disease, and cutting to maintain it in the face of competition from its shade-tolerant associates. Because of the great range in age and associated symptoms of decadence — e.g., decay, insect susceptibility, and lack of windfirmness — the old-growth Douglas-fir stands present a kaleidoscopic picture of conditions. Thus, the land manager must select from a wide range of kinds and intensities of cutting when the objective is to maintain or create an esthetically pleasing forest landscape.

To effectively represent this wide selection, a range of conditions embracing most of those found in old-growth forests was built into this study by setting up 10 hypothetical but realistic model stands. Twelve cutting methods were simulated on each model stand, producing 120 combinations. These methods cover the range of practical proposals for cutting in old-growth stands where esthetic considerations are important.

The Model Stands

Table 1 lists the salient characteristics of the 10 model stands. Two levels of volume inventory were assumed to illustrate the effect of management relative to capital investment. Stands 5 and 10 approximate average simulated forest type conditions. Four variations from each of these average stand conditions (stands 1 to 4 and 6 to 9) are represented to illustrate the financial effect of management practices under different levels of yield and mortality.

Table 1.—Selected old-growth Douglas-fir stand characteristics

Stand number	Original basal area	Original net volume per acre	Growth less cull and breakage	Net unsalvable mortality	Net harvestable yield
	Sq. ft.	M bd. ft.[1]	Bd. ft.[1] per acre per year		
1	400	75	400	0	400
2	400	75	0	0	0
3	400	75	400	400	0
4	400	75	0	400	–400
5	400	75	230	150	80
6	300	60	400	0	400
7	300	60	0	0	0
8	300	60	400	400	0
9	300	60	0	400	–400
10	300	60	230	150	80

[1] Scribner rule.

These four variations and the averages are as follows:

1,6. Zero mortality with high growth = high net harvestable yield gain.

2,7. Zero mortality with low or zero growth = static yield.

3,8. High mortality with high growth = static yield.

4,9. High mortality with low or zero growth = high net harvestable yield loss.

5,10. "Average" mortality with "average" growth = "average" net harvestable yield. The "average" situation, although average in a calculated sense, may not be typical at all as to occurrence in individual stands.

Thus, stands 1 to 4 and 6 to 9 represent extreme conditions. Specifically, site III old-growth Douglas-fir data were used in the course of this study. Stands 5 and 10 represent reasonable averages for high- and low-volume stands on site III. Basal area for all stands is based on site III volume-basal area relations.

Inventory volume is assumed to be 78 percent Douglas-fir and 22 percent other species.

Gross yield less cull and breakage, net unsalvable mortality, and net harvestable yield are assumed to be made up of half Douglas-fir and half other species.

In those simulated harvest operations where overstory trees are removed in the presence of an understory, understory breakage is assumed to be 1,000 board feet per acre. Thereafter, yields from species other than Douglas-fir are reduced 15 percent, irrespective of elapsed time, to account for decay losses from residual stand damage.

Mortality volume is assumed entirely unmerchantable through decay in 20 years. Hence, there will be fractions of 20 years' mortality still merchantable. These fractions range from 100 percent for the current year to 0 percent for the mortality of 20 years ago. The accumulated salvable mortality can be expressed as 50 percent of 20 years' or 10 years' mortality.

Timber Cutting Alternatives Selected for Simulation

A brief description of each simulated management alternative is listed below and designated "A" to "L." Each of these has been applied to each of the 10 model stands.

A. Clearcut and regenerate with Douglas-fir.

B. Shelterwood cut and regenerate with Douglas-fir.

C. Convert to tolerant type with partial cutting.

D. Hold 40 years with mortality harvest and inventory reduction, then clearcut.

E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut.

F. Hold 40 years with mortality harvest, inventory reduction and maintenance; then clearcut.

G. Hold 40 years with mortality harvest, inventory reduction and maintenance; then shelterwood cut.

H. Hold 40 years with yield increment and mortality harvest, then clearcut.

I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut.

J. Hold 40 years with mortality harvest, then clearcut.

K. Remove understory and hold 40 years with mortality harvest, then clearcut.

L. Hold 40 years with no management, then clearcut.

The calculated yields in tables 2 to 11 define more explicitly the simulated cutting alternatives and their yields.

Table 2.—Board-foot yields from selected management alternatives, high volume, high yield; old-growth Douglas-fir stand model (stand No. 1)

Management alternative	Interval in years from present through first yield of second managed rotation																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Thousand board feet per acre, Scribner																	
A. Clearcut and regenerote with Dauglas-fir	75.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Dauglas-fir	53.0	23.2	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Canvert to talerant type (partial cut)	25.0	18.7	12.9	0	24.9	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	--	--	--
D. Hald 40 years with mortality harvest and inventary reduction, then clearcut	25.0	18.7	0	0	39.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
E. Hald 40 years with martolity harvest ond inventary reduction, then shelterwood cut	25.0	18.7	0	0	18.7	21.5	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction ond maintenonce, then cleorcut	25.0	18.7	1.8	1.9	35.2	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
G. Hald 40 years with martality harvest, inventary reduction and maintenance, then shelterwood cut	25.0	18.7	1.8	1.9	15.1	21.3	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
H. Hald 40 years with yield increment ond martality harvest, then clearcut	4.0	3.7	3.7	3.7	71.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remave understory and hald 40 years with yield increment and martality harvest, then cleorcut	18.5	2.0	2.0	2.0	58.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hald 40 years with martality harvest, then clearcut	0	0	0	0	91.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remave understory and hold 40 years with mortality harvest, then clearcut	16.5	0	0	0	66.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hald 40 years with no management, then clearcut	0	0	0	0	91.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 3.—Board-foot yields from selected management alternatives, high volume, static yield, low mortality; old-growth Douglas-fir stand model (stand No. 2)

Management alternative	Interval in years from present through first yield of second managed rotation																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Thousand board feet per acre, Scribner																	
A. Clearcut and regenerate with Douglas-fir	75.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Douglas-fir	53.0	22.0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partial cut)	25.0	16.7	11.1	0	22.2	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	--	--	--
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	25.0	16.7	0	0	33.3	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	25.0	16.7	0	0	11.3	22.0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction and maintenance, then clearcut	25.0	16.7	0	0	33.3	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
G. Hold 40 years with mortality harvest, inventory reduction and maintenance, then shelterwood cut	25.0	16.7	0	0	11.3	22.0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
H. Hold 40 years with yield increment and mortality harvest, then clearcut	0	0	0	0	75.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	16.5	0	0	0	58.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hold 40 years with mortality harvest, then clearcut	0	0	0	0	75.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory and hold 40 years with mortality harvest, then clearcut	16.5	0	0	0	58.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	75.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 4.—Board-foot yields from selected management alternatives, high volume, declining inventory; old-growth Douglas-fir stand model (stand No. 3)

Management alternative	Interval in years from present through first yield of second managed rotation																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Thousand board feet per acre, Scribner																	
A. Clearcut and regenerate with Douglas-fir	75.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Douglas-fir	53.0	22.9	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partial cut)	25.0	18.2	12.4	.9	23.1	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	--	--	--
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	25.0	18.2	1.3	1.3	34.6	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	25.0	18.2	1.3	1.3	12.6	22.9	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction and maintenance, then clearcut	25.0	18.2	1.3	1.3	34.6	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
G. Hold 40 years with mortality harvest, inventory reduction and maintenance, then shelterwood cut	25.0	18.2	1.3	1.3	12.6	22.9	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
H. Hold 40 years with yield increment and mortality harvest, then clearcut	4.0	2.8	2.8	2.8	70.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	18.5	1.5	1.5	1.5	58.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hold 40 years with mortality harvest, then clearcut	4.0	2.8	2.8	2.8	70.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory and hold 40 years with mortality harvest, then clearcut	18.5	1.5	1.5	1.5	58.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	58.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 5.—Board-foot yields from selected management alternatives, high volume, rapidly declining inventory; old-growth Douglas-fir stand model (stand No. 4)

Management alternative	Interval in years from present through first yield of second managed rotation																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Thousand board feet per acre, Scribner																	
A. Clearcut and regenerate with Douglas-fir	75.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Douglas-fir	53.0	21.7	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partial cut)	25.0	16.2	10.6	.9	20.8	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	--	--	--
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	25.0	16.2	1.3	1.2	29.4	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	25.0	16.2	1.3	1.2	7.4	21.7	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction and maintenance, then clearcut	25.0	16.2	1.3	1.2	29.4	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
G. Hold 40 years with mortality harvest, inventory reduction and maintenance, then shelterwood cut	25.0	16.2	1.3	1.2	7.4	21.7	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
H. Hold 40 years with yield increment and mortality harvest, then clearcut	4.0	2.8	2.8	2.8	54.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	18.5	1.5	1.5	1.5	50.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hold 40 years with mortality harvest, then clearcut	4.0	2.8	2.8	2.8	54.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory and hold 40 years with mortality harvest, then clearcut	18.5	1.5	1.5	1.5	50.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	59.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 6.—Board-foot yields from selected management alternatives, high volume, average mortality, average yield; old-growth Douglas-fir stand model (stand No. 5)

Management alternative	Interval in years from present through first yield of second managed rotation																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	—Thousand board feet per acre, Scribner—																	
A. Clearcut and regenerate with Douglas-fir	75.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Douglas-fir	53.0	22.5	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partial cut)	25.0	17.65	12.0	.35	22.95	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	--	--	--
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	25.0	17.65	.5	.5	35.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	25.0	17.65	.5	.5	13.6	21.9	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction and maintenance, then clearcut	25.0	17.65	.9	.9	34.2	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
G. Hold 40 years with mortality harvest, inventory reduction and maintenance, then shelterwood cut	25.0	17.65	.9	.9	12.6	22.1	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
H. Hold 40 years with yield increment and mortality harvest, then clearcut	2.3	1.75	1.75	1.75	70.6	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	17.65	.95	.95	.95	58.35	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hold 40 years with mortality harvest, then clearcut	1.5	1.0	1.0	1.0	73.9	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory and hold 40 years with mortality harvest, then clearcut	17.25	.55	.55	.55	59.95	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	78.2	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 7.—Board-foot yields from selected management alternatives, low volume, high yield; old-growth Douglas-fir stand model (stand No. 6)

Management alternative	Interval in years from present through first yield of second managed rotation																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Thousand board feet per acre, Scribner																	
A. Clearcut and regenerate with Douglas-fir	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Douglas-fir	36.0	25.6	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partial cut)	20.0	15.3	0	30.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	--	--	--
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	20.0	0	0	0	48.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	20.0	0	0	0	25.4	24.2	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction and maintenance, then clearcut	20.0	2.0	2.0	2.0	42.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
G. Hold 40 years with mortality harvest, inventory reduction and maintenance, then shelterwood cut	20.0	2.0	2.0	2.0	19.7	23.9	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
H. Hold 40 years with yield increment and mortality harvest, then clearcut	4.0	3.7	3.7	3.7	46.8	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	15.2	2.0	2.0	2.0	46.8	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hold 40 years with mortality harvest, then clearcut	0	0	0	0	76.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory and hold 40 years with mortality harvest, then clearcut	13.2	0	0	0	54.8	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	76.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 8.—Board-foot yields from selected management alternatives, low volume, static yield, low mortality; old-growth Douglas-fir stand model (stand No. 7)

Management alternative	Intervol in yeors from present through first yield of second managed rototion																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	—Thousond baord feet per ocre, Scribner—																	
A. Clearcut ond regenerate with Douglas-fir	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwaod cut ond regenerote with Douglos-fir	36.0	24.0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partiol cut)	20.0	13.3	0	26.7	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	--	--	--
D. Hold 40 years with mortolity horvest and inventory reduction, then cleorcut	20.0	0	0	0	40.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
E. Hold 40 years with mortolity harvest ond inventory reduction, then shelterwaod cut	20.0	0	0	0	15.6	24.4	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
F. Hald 40 years with mortality harvest, inventory reductian ond mointenonce, then clearcut	20.0	0	0	0	40.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
G. Hald 40 years with mortality harvest, inventory reductian ond maintenance, then shelterwaad cut	20.0	0	0	0	15.6	24.4	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
H. Hald 40 years with yield increment and mortality harvest, then clearcut	0	0	0	0	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remave understory ond hold 40 years with yield increment ond mortality harvest, then clearcut	13.2	0	0	0	46.8	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hald 40 years with mortolity harvest, then clearcut	0	0	0	0	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory ond hold 40 years with mortality horvest, then cleorcut	13.2	0	0	0	46.8	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 9.—Board-foot yields from selected management alternatives, low volume, declining inventory; old-growth Douglas-fir stand model (stand No. 8)

Management alternative	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Interval in years from present through first yield of second managed rotation																	
	Thousand board feet per acre, Scribner																	
A. Clearcut and regenerate with Douglas-fir	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Douglas-fir	36.0	25.2	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partial cut)	20.0	14.8	1.3	28.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	--	--	--
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	20.0	1.5	1.5	1.5	41.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	20.0	1.5	1.5	1.5	17.1	25.6	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction and maintenance, then clearcut	20.0	1.5	1.5	1.5	41.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
G. Hold 40 years with mortality harvest, inventory reduction and maintenance, then shelterwood cut	20.0	1.5	1.5	1.5	17.1	25.6	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0
H. Hold 40 years with yield increment and mortality harvest, then clearcut	4.0	2.8	2.8	2.8	55.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	15.2	1.5	1.5	1.5	46.3	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hold 40 years with mortality harvest, then clearcut	4.0	2.8	2.8	2.8	55.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory and hold 40 years with mortality harvest, then clearcut	15.2	1.5	1.5	1.5	46.3	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 10.—Board-foot yields from selected management alternatives, low volume, rapidly declining inventory; old-growth Douglas-fir stand model (stand No. 9)

Management alternative	Interval in years from present through first yield of second managed rotation																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Thousand board feet per acre, Scribner																	
A. Clearcut and regenerate with Douglas-fir	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Douglas-fir	36.0	23.6	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partial cut)	20.0	12.8	1.3	24.5	0	0	1.0	3.5	3.5	5.5	4.5	4.0	3.5	7.0	7.0	6.0	0	1.0
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	20.0	1.5	1.5	1.5	33.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	23.8	0	1.0
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	20.0	1.5	1.5	1.5	8.5	24.6	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	0	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction and maintenance, then clearcut	20.0	1.5	1.5	1.5	33.5	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	23.8	0	1.0
G. Hold 40 years with mortality harvest, inventory reduction and maintenance, then shelterwood cut	20.0	1.5	1.5	1.5	8.5	24.6	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	0	0	1.0
H. Hold 40 years with yield increment and mortality harvest, then clearcut	4.0	2.8	2.8	2.8	39.2	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	15.2	1.5	1.5	1.5	38.3	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hold 40 years with mortality harvest, then clearcut	4.0	2.8	2.8	2.8	39.2	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory and hold 40 years with mortality harvest, then clearcut	15.2	1.5	1.5	1.5	38.3	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	43.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Table 11.—Board-foot yields from selected management alternatives, low volume, average mortality, average yield; old-growth Douglas-fir stand model (stand No. 10)

Management alternative	Interval in years from present through first yield of second managed rotation																	
	Present	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Thousand board feet per acre, Scribner																	
A. Clearcut and regenerate with Douglas-fir	60.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0	--	--	--	--
B. Shelterwood cut and regenerate with Douglas-fir	36.0	24.8	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	23.8	0	1.0	--	--	--	--
C. Convert to tolerant type (partial cut)	20.0	14.25	0.5	27.9	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	7.0	7.0	0	0	1.0
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	20.0	.55	.55	.55	42.2	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	23.8	0	1.0
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	20.0	.55	.55	.55	18.05	24.9	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	0	0	1.0
F. Hold 40 years with mortality harvest, inventory reduction and maintenance, then clearcut	20.0	.95	.95	.95	41.0	0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	23.8	0	1.0
G. Hold 40 years with mortality harvest, inventory reduction and maintenance, then shelterwood cut	20.0	.95	.95	.95	16.75	25.0	0	1.0	3.5	5.5	5.5	4.5	4.0	3.5	23.9	0	0	1.0
H. Hold 40 years with yield increment and mortality harvest, then clearcut	2.3	1.75	1.75	1.75	55.6	0	0	0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	14.35	.95	.95	.95	46.55	0	0	0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
J. Hold 40 years with mortality harvest, then clearcut	1.5	1.0	1.0	1.0	58.8	0	0	0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
K. Remove understory and hold 40 years with mortality harvest, then clearcut	13.95	.55	.55	.55	48.25	0	0	0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0
L. Hold 40 years with no management, then clearcut	0	0	0	0	63.2	0	0	0	3.5	5.5	5.5	4.5	4.0	3.5	47.5	0	0	1.0

Special treatment accorded landscape management areas precludes consideration of clearcutting as an alternative. Nevertheless, this alternative is included in this evaluation, because our purpose is to expose economic consequences of alternative kinds of timber cutting (figs. 5 and 6). In certain cases, such cutting may, in fact, be used as a landscape technique to greater advantage than other cutting methods. An example is the occasional need to clear away roadside obstructions to permit viewing adjacent scenery, such as a lake, stream, or mountain. Scalloping the edges of a clearcut — i.e, designing the shape of the clearcut to avoid abrupt lines — may help reduce the negative impact of the cutting. It may also develop that clearcutting immediately may be the most effective or fastest way to gain control of or convert the stand for both its esthetic and financial yield.

Figure 5.--A clearcut immediately following logging and burning.

Figure 6.–A clearcut about 10 years after logging.

Seed-tree or patch selection cutting was not considered, since it did not seem to differ significantly from clearcutting in esthetic impact and seemer to provide no silvicultural superiority for old-growth Douglas-fir management over other methods considered.

Shelterwood cutting was chosen because it promises to combine desirable aspects of timber production and esthetic yield. Although never studied specifically for Douglas-fir, shelterwood cutting appears technically feasible, based on Isaac's (1943 and 1956) observations. Furthermore, it seems especially suited for opening up a stand for visual penetration — a desirable esthetic characteristic (figs. 7 and 8).

Figure 7.–Shelterwood unit immediately after logging.

Figure 8.--Shelterwood unit about 10 years after initial logging.

Conversion to a shade-tolerant type through partial or selection cutting is a broad alternative class that is frequently considered for modifying cutting in old growth to favor esthetics (fig. 9). A consequence, however, as the class name implies, is that partial or selection cutting

Figure 9.--Selective cutting for conversion of stand to shade-tolerant species.

tends to favar the shade-tolerant associates af Douglas-fir, such as hemlock, and very likely will result in a species-type change. Althaugh the esthetic cansequences of type change may be small, the shift in stand composition to these currently lower valued associates of Dauglas-fir may have a big financial yield impact.

Several alternatives invalve holding the existing stand for 40 years with light-to-na cutting (fig. 10). This period is then fallowed by either

Figure 10.--An uncut old-growth Douglas-fir stand.

clearcut ar shelterwaad silvicultural systems. Althaugh there is na great technical ar economic significance to the 40-year periad, this period seemed lang enaugh to test the effect of deferred harvest cutting in old-growth stands. Eventually, harvest cutting will be required; just what kind will depend on the stand canditian (in terms of species campositian, tree size and spacing, etc.) the manager wants to create. This, in turn, will depend an bath financial yield and appearance.

Timber Yields

Estimated yields fram the old-growth examples were based on the faregoing stand characteristics and assumptions regarding martality and yield. Tables 2 through 11 shaw the results af yield calculations fram the present thraugh the first yield af the second managed rotation.[5] The cutting schedules simulated in this study represent reasonable practices but do nat necessarily represent optimum ecanamic or esthetic schedules.

Future stand yields are based essentially on the illustrative valuation table, table 16, in Technical Bulletin 1230 (Worthington and Staebler 1961). Tables 12, 13, and 14 show future valume and value yield estimates far managed stands.

Future yields fram more tolerant species on sites occupied by Douglas-fir are not directly determinable from any available yield tables. The hemlock yield tables developed by Barnes (1962) identify yield by hemlack site classification. Thus far, no correlation has been made that will indicate the productivity af a hemlock stand an a Douglas-fir rated site. Dimock (1958), however, shows much higher early yields far hemlack stands than cauld be expected for Douglas-fir stands on the same Douglas-fir site. This is apparently an expression of early grawth that is nat reflected by alder stands.

Because of the lack of appropriate data, however, the assumption is made that Dauglas-fir stands an site III, when converted to more talerant associated species, will yield the same total volume aver the ratation. Further, hemlock stands are assumed to yield the same additianal volume through thinnings as Dauglas-fir. Therefore, the production schedule assumed by Worthington and Staebler far Douglas-fir on site III is alsa assumed far hemlock.

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[5] 100-yeor rototions hove been ossumed even though it has been decided to carry timber in some roadside oreas, on the Notionol Forests for exomple, to the 300-yeor-oge level ond longer. This stond-by-stond onolysis requires, however, thot o single rototion oge be used for comporing olternotive cutting schemes. 100-yeor rototions were considered odequote for comporing the olternotives in this study. Longer rototions would chonge the colculoted yields ond present volues but would not chonge the relotive economic desirobility of the olternotives with respect to eoch other.

The colculotions in tobles 2 through 11 ore shown only through the first yield of the second monoged rototion simply to illustrote the full ronge of cutting schedules ond periodic yields for eoch olternotive.

Table 12.—Clearcut management yields for Douglas-fir site III

Item	Stand age	Volume[1] per acre	Stumpage value per thousand board feet	Total value		
				Gross	Adminis-trative[2]	Net[3]
	Years	M bd. ft.	Dollars			
Thinned stand:						
Thinnings	25-35	1.0	5.00	5.00	4.00	1.00
	35-45	3.5	7.50	26.25	14.00	12.25
	45-55	5.5	12.00	66.00	22.00	44.00
	55-65	5.5	15.00	82.50	22.00	60.50
	65-75	4.5	17.50	78.75	18.00	60.75
	75-85	4.0	20.00	80.00	16.00	64.00
	85-95	3.5	25.00	87.50	14.00	73.50
Total		27.5		426.00	110.00	316.00
Final harvest (clearcut)	100	47.5	30.00	1,425.00	95.00	1,330.00
Total yield		75.0		1,851.00	205.00	1,646.00
Unthinned stand:						
Final harvest (clearcut)	100	62.8	25.00	1,570.00	125.60	1,444.40

[1] From Staebler (1955), Scribner rule.
[2] Administration at $4 per thousand board feet per acre for all partial cuts and $2 per thousand board feet per acre for clearcuts.
[3] Net equals gross minus administrative costs.

Table 13.—Shelterwood management yields for Douglas-fir site III

Item	Stand age	Volume[1] per acre	Stumpage value per thousand board feet	Total value		
				Gross	Adminis-trative[2]	Net[3]
	Years	M bd. ft.	Dollars			
Thinned stand:						
Thinnings	25-35	1.0	5.00	5.00	4.00	1.00
	35-45	3.5	7.50	26.25	14.00	12.25
	45-55	5.5	12.00	66.00	22.00	44.00
	55-65	5.5	15.00	82.50	22.00	60.50
	65-75	4.5	17.50	78.75	18.00	60.75
	75-85	4.0	20.00	80.00	16.00	64.00
	85-95	3.5	25.00	87.50	14.00	73.50
Total		27.5		426.00	110.00	316.00
Shelterwood (initial)	100	23.9	25.00	597.50	95.60	501.90
Shelterwood (final)	110	23.8	27.50	654.50	95.20	559.30
Total yield		75.2		1,678.00	300.80	1,377.20
Unthinned stand: (None)[4]						

[1] From Staebler (1955), Scribner rule.
[2] Administration at $4 per thousand board feet per acre for all partial cuts and $2 per thousand board feet per acre for clearcuts.
[3] Net equals gross minus administrative costs.
[4] A thinning program is assumed whenever final harvest is by shelterwood cutting.

Table 14.—Yields for conversion to tolerant type and partial-cut management for Douglas-fir site III

Item	Stand age	Volume[1] per acre	Stumpage value[2] per thousand board feet[3]	Total value: Gross	Total value: Adminis-trative[4]	Total value: Net[5]
	Years	M bd. ft.[3]	Dollars			
Thinned stand:						
Thinnings	25-35	1.0	5.00	5.00	4.00	1.00
	35-45	3.5	5.00	17.50	14.00	3.50
	45-55	5.5	5.00	27.50	22.00	5.50
	55-65	5.5	5.50	30.25	22.00	8.25
	65-75	4.5	7.00	31.50	18.00	13.50
	75.85	4.0	8.00	32.00	16.00	16.00
	85-95	3.5	9.00	31.50	14.00	17.50
Tatal		27.5		175.25	110.00	65.25
Sustained yield[6]	100	7.0	10.00	70.00	28.00	42.00[7]
Tatal yield		34.5		245.25	138.00	107.25
Unthinned stand: Sustained yield[8]	100	5.0	10.00	50.00	20.00	30.00[7]

[1] Thinning valumes same as Staebler (1955) far Dauglas-fir.
[2] Stumpage value increased fram $5 to $10 at same rate as Staebler's Dauglas-fir stumpage valume increased.
[3] Fram Staebler (1955), Scribner rule.
[4] Administratian at $4 per thausand board feet per acre far all partial cuts.
[5] Net equals grass minus administrative casts.
[6] Sustained yield based an growth at age 80 (Barnes 1962), the age of stacking carried here.
[7] Assume this yield perpetuated to infinity.
[8] Sustained yield based on Barnes' (1962) yield table at age 90 less 1,000 baard feet for breakage.

Worthington and Staebler (1961) indicate a yield increase, due to thinning, from 62,800 to 75,200 board feet per acre in 100 years. They reducued final yield to 47,700 by thinning. We assume a yield of 47,500 and the same schedule for hemlock and continuous net yield increments under partial cut management equivalent to that at yield table age 80, the age of the stand density indicated in our example. The oldest trees after any 10-year yield cut will be 90 years.

Extra breakage from the upper crown of 1,000 board feet per acre, previously estimated for partial cuts, is deducted from the growth to give a 10-year volume-yield increment of 7,000 board feet per acre. For the unthinned hemlock stand, 10-year growth and volume-yield increment is taken as approximately that at age 90 in the yield table, since the oldest members will be 90 years after any 10-year yield harvest. Breakage of 1,000 board feet per acre is deducted to give a 10-year volume-yield increment of 5,000 board feet per acre in the unthinned stand.

The entire yield in all future stands is treated as sound volume. The actual proportion of sound volume should be very high in managed stands. The yield schedules used are described by Worthington and Staebler (1961) as "highly conservative."

Value Yields

Economic evaluation is based on calculated present net worths, in terms of net stumpage value, for all present and future timber yields obtained from the alternative cutting programs used in this study. A number of assumptions are implied or made explicit in the following discussion of values used in the calculations. Although the values used are considered realistic, if conservative, the absolute levels of value are not as important for the purpose of this study as the **way** in which they are used.

Current Net Stumpage Values

Net stumpage values assumed for yields from existing stands are shown in table 15. Douglas-fir stumpage prices, on the National Forests of Region 6 at least, increased from an average of $24.80 in 1962 to an average of $38.10 in 1964 (Hamilton 1964). However, the appraised value of Douglas-fir sawtimber in western Oregon and Washington during 1964 averaged around $24 per thousand board feet. The assumption for current price expectations for this study was $32 per thousand board feet for Douglas-fir sawtimber. This value was used throughout the assumed 40-year conversion or holding period for existing stands in all alternatives.

Table 15.—Stumpage value assumptions for yields from existing old-growth stands

Management alternative group	Species		
	Douglas-fir	Other	Average stand composition[1]
	— — — Dollars per M bd. ft.[2] — — —		
Clearcut	32	12	28
Shelterwood cut	30	10	26
Partial cutting	28	8	24

[1] 78 percent Douglas-fir and 22 percent other species assumed.
[2] Scribner rule.

Logging costs per unit of stumpage yield are expected to increase somewhat as cutting alternatives move from clearcutting through lesser intensities of partial cutting. The exact dollar difference between these broad classes of alternatives is not known. However, in table 15 the difference between alternative cutting methods is assumed to be $2 per thousand board feet. Although this difference may understate the differences in average logging costs between the cutting alternatives, it conforms to the general pattern of differences based upon removal of lesser volumes per acre.

Unit stumpage values for species associated with Douglas-fir average around a third of the value of Douglas-fir. The values for "other" species in table 15 reflect this relative value.

Average stand composition for existing old-growth Douglas-fir stands is assumed to be 78 percent Douglas-fir and 22 percent "other" species, including mainly western hemlock. The stumpage values for "average stand composition" in table 15 are based on this assumption.

Administrative Costs

Timber sale administration costs have also been accounted for. Worthington and Fedkiw (1964) estimated costs of $2.25 per thousand board feet for marking, selling, and supervising the sale of thinnings in one case study. When sales are laid out in which esthetics are also to be considered, such costs could be much higher because of increased time and care in designing boundaries of cutting units and marking individual trees for removal. In this study, administrative costs of this type have been assumed to be $4 and $2 per thousand board feet, respectively, for partial cutting and for clearcutting.

Stumpage Values for Future Stands

The value of timber 40 years and more hence is difficult to forecast. One recent study (U.S. Forest Service 1963) assumed that sawtimber trees (11 inches or larger d.b.h. to a minimum 8-inch top) would yield an average of $40 per thousand board feet in the future in the Douglas-fir subregion. For the purposes of this study, however, lower net stumpage values were assumed. These were based on the expectation of smaller sizes of timber than current old-growth timber because of the assumed shorter rotation of 100 years.

Table 16 shows the range of net stumpage values assumed for yields from future stands. These values are more fully developed in tables 12, 13, and 14. The thinning values estimated by Worthington and Staebler (1961) have been adjusted upward to conform with more recent experience. Thinnings from recent National Forest timber sales in stands ranging in age from 30 to 100 years have yielded stumpage values from $5 to $30 per thousand board feet.

Table 16.—Stumpage value assumptions for future stand yields, Douglas-fir type, site III

Yield category	Species	
	Douglas-fir	Tolerant associates
	— — — Dollars per thousand board feet[1] — — —	
Final harvest (includes shelterwood)	25-30	--
Thinnings	5-25	5-9
Sustained yield harvest	--	10

[1] Scribner rule.

Calculation of Dollar Yields

The assumed volume yield for each stand treated by each of the 12 cutting methods shown in tables 2 through 11 was multiplied by the appropriate stumpage value from tables 12 to 16. For example, the current yield of 75,000 board feet per acre from stand number 1 — table 2 — under clearcutting was multiplied by $28 — from table 15 — for a total current stumpage value of $2,100 per acre. Administrative costs of $2 per thousand board feet were then deducted to give a net dollar yield per acre of $1,950. With the same stand and cutting alternative combination, additional stumpage value calculations were made as shown in table 17. Calculation results for shelterwood cutting and conversion-to-tolerant-species alternatives for the same stand are shown in tables 18 and 19. Table 20 shows similar illustrative data for the first of the deferred cutting alternatives in the high-volume, high-yield model stand.

Table 17.—Dollar value yield calculations; high-volume, high-yield model stand under clear-cutting alternative, Douglas-fir site III

Time from present (years)	Yield[1]	Stumpage value per thousand board feet[2]	Yield per acre less administrative costs[3]
	M bd. ft.[4]	Dollars	Dollars
Present	75.0	28.00	1,950.00
30	1.0	5.00	1.00
40	3.5	7.50	12.25
50	5.5	12.00	44.00
60	5.5	15.00	60.50
70	4.5	17.50	60.75
80	4.0	20.00	64.00
90	3.5	25.00	73.50
100	47.5	30.00	1,330.00
130	1.0	5.00	1.00

[1] From table 2.
[2] From table 12, except for "present" which is from table 15.
[3] Administrative costs of $4 and $2 per thousand board feet assumed for all partial and clearcuts, respectively.
[4] Scribner rule.

Table 18.—Dollar value yield calculations; high-volume, high-yield model stand under shelterwood cutting alternative, Douglas-fir site III

Time from present (years)	Yield[1]	Stumpage value per thousand board feet[2]	Yield per acre less administrative costs[3]
	M bd. ft.[4]	Dollars	Dollars
Present	53.0	26.00	1,166.00
10	23.2	26.00	510.40
30	1.0	5.00	1.00
40	3.5	7.50	12.25
50	5.5	12.00	44.00
60	5.5	15.00	60.50
70	4.5	17.50	60.75
80	4.0	20.00	64.00
90	3.5	25.00	73.50
100	23.9	25.00	501.90
110	23.8	27.50	559.30
130	1.0	5.00	1.00

[1] From table 2.
[2] From table 13, except for "present" and "10 years," which are from table 15.
[3] Administrative costs of $4 per thousand board feet assumed for all partial cuts.
[4] Scribner rule.

Table 19.—Dollar value yield calculations; high-volume, high-yield model stand under conversion-to-tolerant-species alternative, Douglas-fir site III

Time from present (years)	Yield[1]	Stumpage value per thousand board feet	Yield per acre less administrative costs[2]
	M bd. ft.[3]	Dollars	
Present	25.0	24.00[4]	500.00
10	18.7	24.00[4]	374.00
20	12.9	24.00[4]	258.00
40	24.9	24.00[4]	498.00
60	1.0	5.00[5]	1.00
70	3.5	5.00[5]	3.50
80	5.5	5.00[5]	5.50
90	5.5	5.50[5]	8.25
100	4.5	7.00[5]	13.50
110	4.0	8.00[5]	16.00
120	3.5	9.00[5]	17.50
130	7.0	10.00[5]	42.00
140	7.0	10.00[5]	42.00

[1] From table 2.
[2] Administrative costs of $4 per thousand board feet assumed for all partial cuts.
[3] Scribner rule.
[4] From table 15.
[5] From table 14.

Table 20.—Dollar value yield calculations; high-volume, high-yield model stand, holding existing stands 40 years with mortality harvest and inventory reduction followed by clearcutting, Douglas-fir site III

Time from present (years)	Yield[1]	Stumpage value per thousand board feet	Yield per acre less administrative costs[2]
	M bd. ft.[3]	Dollars	
Present	25.0	24.00[4]	500.00
10	18.7	24.00[4]	374.00
40	39.0	24.00[4]	780.00
70	1.0	5.00[5]	1.00
80	3.5	7.50[5]	12.25
90	5.5	12.00[5]	44.00
100	5.5	15.00[5]	60.50
110	4.5	17.50[5]	60.75
120	4.0	20.00[5]	64.00
130	3.5	25.00[5]	73.50
140	47.5	30.00[5]	1,330.00
170	1.0	5.00[5]	1.00

[1] From table 2.
[2] Administrative costs of $4 and $2 per thousand board feet assumed for all partial and clearcuts, respectively.
[3] Scribner rule.
[4] From table 15.
[5] From table 12.

It should be noted that the last yield shown in tables 17 to 20 is the first yield of what is called here the "second managed rotation." From this point in time, cutting cycles and yields of the succeeding rotation are assumed to begin anew in the same pattern to infinity. For example, the shelterwood cutting alternative in the high-volume, high-yield stand of tables 2 and 18 shows a per-acre yield of 1,000 board feet, or $1 net in the 130th year from the present. This is equivalent to the initial thinning yield of the first managed rotation for the 30th year from the present and is the assumed initial yield from all rotations thenceforth.

It will also be noted that, with the exception of the conversion-to-tolerant-species alternative, all methods assume thinning programs.

Natural regeneration was assumed in all cases, and yield periods reflect some regeneration time. Hence, no regeneration costs were deducted from value yields. Undoubtedly, regeneration costs would be incurred with the clearcutting alternative. Such costs for regenerating clearcut areas vary from less than $7 to over $100 per acre (Payne 1964). However, such costs, when known, can be deducted from the present worths calculated below if a more detailed analysis is desired.

Calculation of Present Worth

The values of all future yields for all stands and alternatives were discounted back to the present in order to compare the alternatives in terms of dollar values. Two discount rates were used to reflect varying costs of financing. It is assumed that government (principally the Federal Government) would have to pay 3 percent interest on funds borrowed to finance its activities in lieu of other income — as in the case of reduced present stumpage returns to the treasury resulting from reduced current timber yields to favor esthetics. The 6-percent rate represents the cost of capital paid by some private firms. Present worth calculations specifically for private firms would have to be modified slightly to reflect economic factors of private management that are not common to public management; specifically, property tax and the income tax.

Discounting for each management alternative was done generally in two stages:

1. Each net dollar yield from existing old-growth stands was discounted to the present separately with the formula:

$$V_o = \frac{V_n}{(1+i)^n}$$

where,

V_o = value at the present time (dollars)

V_n = value of future yield (dollars)

n = number of years hence that yield occurs

i = annual rate of interest (decimal)

The calculated present values were then added together to obtain a total net present stumpage value for the yields from the existing old-growth stand over the period of its conversion to a fully regulated stand. This period ranges from 0 years with the clearcutting alternative to 50 years with two of the deferred harvest alternatives.

2. A two-step procedure was used to discount net value yields from the thinning and harvest cut programs in the managed young-growth stands of the future. The procedure involved discounting yield values to the beginning of the first managed rotation. This discounted present value was then discounted to the present over the period required to liquidate the original old-growth stand.

a. Step 1:

The first step — discounting end-of-rotation values for all future rotations — used the following formula:

$$V_{o+c} = \frac{a}{(1+i)^n - 1}$$

where,

V'_{o+c} = present value at beginning of first managed rotation (present time + period required to convert or liquidate existing old-growth stand)

a[6] = financial value of stand at end of each managed rotation

n = 100 years

b. Step 2:

The second step — discounting the present worth of all future managed rotations at the beginning of the first rotation — was accomplished with the formula:

$$V_o = \frac{V_{o+c}}{(1+i)^k}$$

where,

V_o = present value of all yields

V_{o+c} = present value of all future managed rotations at beginning of first managed rotation

k = number of years from present that the last harvest from original old-growth stand is taken. This marks the beginning of the first rotation.

The present values from both stages — i.e., the present value of the old-growth stand and the present value of the future managed stands — were added together to obtain the total present value.

Present values for each cutting-method alternative, and for the 3-percent and 6-percent discount rates, are shown in table 21. These were calculated with an IBM 7040 computer.[7]

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[6] The value, a, is calculated as follows:

$$a = y_1 (1+i)^{n-t_1} + y_2 (1+i)^{n-t_2} + \dots y_n (1+i)^{n-t_n}$$

where,

$y_1 \dots y_n$ = dollar yield at years 1 to n

$n-t_1 \dots n-t_n$ = number of years before end of rotation; for example, if the first yield (y_1) occurs 30 years after the start of a 100-year rotation, $n-t_1$ would equal 70 years

[7] The FORTRAN IV program listing and source deck (coded by Dan Chappelle) are available on request from the Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Table 21.—Present value of stumpage yields for 10 model stand conditions, 12 management alternatives, interest rates of 3 and 6 percent, in old-growth Douglas-fir site III

Management alternative	Stand value at 3-percent interest rate, for stand model									
	1	2	3	4	5	6	7	8	9	10
	Dollars per acre									
A. Clearcut and regenerate with Douglas-fir	2,068.68	2,068.68	2,068.68	2,068.68	2,068.68	1,678.68	1,678.68	1,678.68	1,678.68	1,678.68
B. Shelterwood cut and regenerate with Douglas-fir	1,535.85	1,516.21	1,530.94	1,511.30	1,524.39	1,235.14	1,208.95	1,228.59	1,202.40	1,222.05
C. Convert to tolerant type (partial cut)	1,080.85	1,014.60	1,064.26	1,000.46	1,046.17	886.05	824.98	872.41	813.81	853.80
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	1,125.52	1,050.33	1,108.12	1,036.08	1,086.93	818.96	755.20	499.63	754.69	793.25
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	1,030.29	957.66	1,017.58	949.09	994.31	706.63	647.54	714.06	656.31	685.29
F. Hold 40 years with mortality harvest inventory reduction and maintenance, then clearcut	1,130.82	1,050.33	1,108.12	1,036.08	1,088.28	839.53	755.20	818.45	754.69	797.37
G. Hold 40 years with mortality harvest inventory reduction and maintenance, then shelterwood cut	1,042.80	957.66	1,017.58	949.09	996.41	738.56	647.54	714.06	656.31	692.11
H. Hold 40 years with yield increment and mortality harvest, then clearcut	808.81	634.17	770.06	642.53	706.65	615.92	514.61	650.50	524.57	587.09
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	941.05	832.65	919.96	856.20	888.05	781.79	673.40	760.71	696.94	730.00
J. Hold 40 years with mortality harvest, then clearcut	761.70	634.17	770.06	642.53	689.60	642.14	514.61	650.50	524.57	569.24
K. Remove understory and hold 40 years with mortality harvest, then clearcut	896.42	832.65	919.96	856.20	879.13	737.16	673.40	760.71	696.94	721.08
L. Hold 40 years with no management, then clearcut	761.70	634.17	502.65	506.64	659.67	642.14	514.61	514.61	379.11	540.12

Table 21.—Continued

Management alternative	Stand value at 6-percent interest rate, for stand model									
	1	2	3	4	5	6	7	8	9	10
	Dollars per acre									
A. Clearcut and regenerate with Douglas-fir	1,961.56	1,961.56	1,961.56	1,961.56	1,961.56	1,571.56	1,571.56	1,571.56	1,571.56	1,571.56
B. Shelterwood cut and regenerate with Douglas-fir	1,355.04	1,340.30	1,351.36	1,336.62	1,346.44	1,044.53	1,024.87	1,039.61	1,019.96	1,034.70
C. Convert to tolerant type (partial cut)	838.02	799.21	828.95	790.92	817.82	677.39	641.82	671.21	636.69	659.17
D. Hold 40 years with mortality harvest and inventory reduction, then clearcut	808.55	771.80	804.47	763.65	791.01	522.46	502.24	436.25	517.13	520.33
E. Hold 40 years with mortality harvest and inventory reduction, then shelterwood cut	771.86	735.73	768.72	734.49	754.99	479.27	460.45	496.13	478.21	478.25
F. Hold 40 years with mortality harvest inventory reduction and maintenance, then clearcut	816.78	771.80	804.47	768.65	792.88	549.06	502.24	537.36	517.13	525.65
G. Hold 40 years with mortality harvest inventory reduction and maintenance, then shelterwood cut	782.46	735.73	768.72	734.49	757.05	509.60	460.45	496.13	478.21	484.39
H. Hold 40 years with yield increment and mortality harvest, then clearcut	337.88	190.71	316.55	276.11	263.18	276.70	152.79	278.63	238.69	225.26
I. Remove understory and hold 40 years with yield increment and mortality harvest, then clearcut	560.77	479.00	549.06	528.84	521.63	465.20	383.42	453.49	433.27	427.80
J. Hold 40 years with mortality harvest, then clearcut	231.15	190.71	316.55	276.11	238.81	193.24	152.79	278.63	238.69	200.64
K. Remove understory and hold 40 years with mortality harvest, then clearcut	499.22	479.00	549.06	528.84	509.32	403.65	383.42	453.39	433.27	415.49
L. Hold 40 years with no management, then clearcut	231.15	190.71	149.00	150.26	198.80	193.24	152.79	152.79	109.82	160.88

Figures 11 and 12 graphically show these values for the "average" conditions of stands 5 and 10.

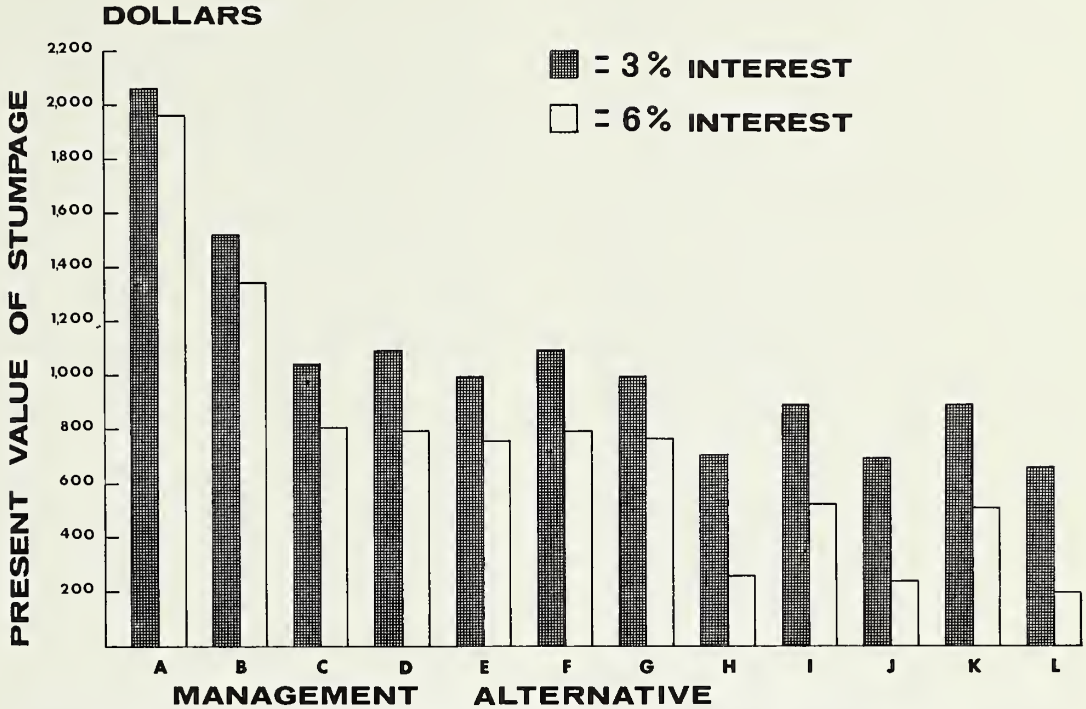

Figure 11.--Present value of stumpage yields from stand 5 for 12 management alternatives at 3 and 6 percent interest for Douglas-fir site III.

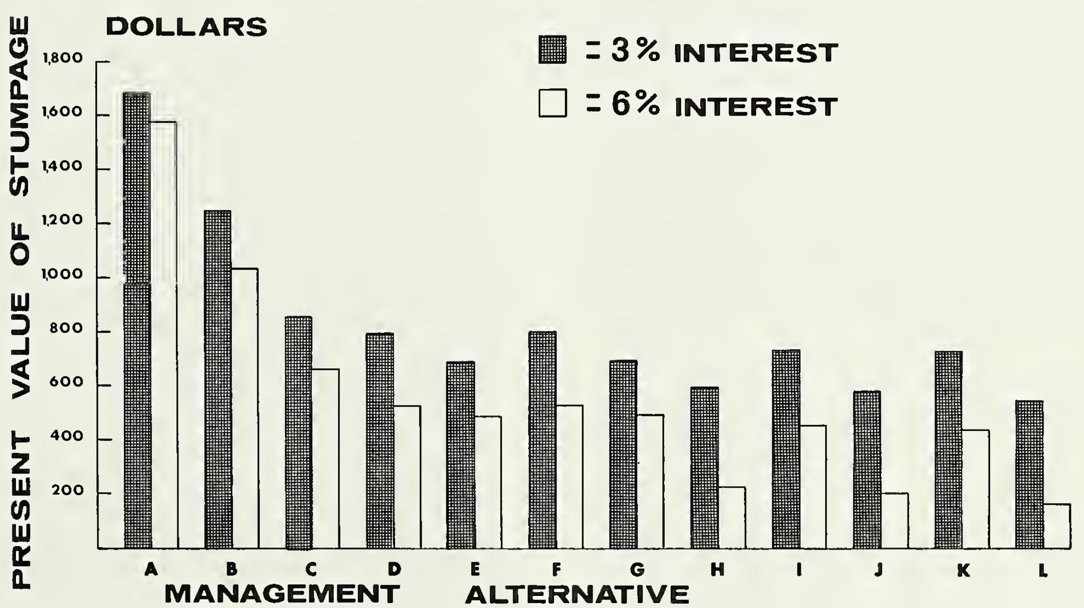

Figure 12.--Present value of stumpage yields from stand 10 for 12 management alternatives at 3 and 6 percent interest for Douglas-fir site III.

Discussion

As expected, the clearcutting alternative yields the highest present stumpage values for all model stands. This result is most strongly influenced by the fact that there is no waiting time for the initial yield — which is also the entire net volume of the stand — and, hence, no interest or discount cost. Also, future yields from thinnings begin to occur earlier than in other alternatives and the final harvest occurs sooner than under the shelterwood alternative.

To the extent that clearcutting is a feasible alternative in at least part of the area where increased emphasis is given to esthetic yield, and to the extent that maximum present stumpage value is the criterion of desirability, clearcutting would rank as the economically best alternative of this study.

Judged by the same criterion — i.e., maximum present value of stumpage yield — the two-cut shelterwood system of this study ranks second best. The difference in present value between clearcutting and shelterwood cutting ranges from approximately $400 to $600 an acre, depending principally upon the discount rate. In effect, we would forgo from $400 to $600 an acre of value by choosing shelterwood cutting. This indicates, moreover, that if shelterwood cutting provides the desired stand appearance, one of the "prices" paid for this appearance is the forgone $400 to $600 per acre which could have been obtained from clearcutting.

Conversion to a tolerant species yields even lower present values than shelterwood cutting, by some $400 to $500 an acre. This is the result not only of waiting or discount costs, but also of the relatively lower value assumed for future stands which are made up of species other than Douglas-fir.

Present value yields of the remaining alternatives are progressively lower as the harvesting of the bulk of the existing old-growth stand is pushed farther toward the end of its conversion period.

These results can be used for broad comparisons of management alternatives. They can also be used when the range of alternatives is restricted. For example, a decision may already have been made to hold the existing old-growth stand relatively intact for 40 years, thus eliminating immediate clearcutting, shelterwood cutting, or conversion-to-tolerant-species cutting. Suppose further, that no clearcutting is ever to be permitted. These decisions would eliminate all but the two alternatives involving mortality salvage and inventory reduction followed by shelterwood cutting. One of the alternatives, however, involves removing some 4,000 board feet more during the 40-year conversion period. This heavier intermediate cutting alternative thus yields somewhat higher present values in four of the model stands than the other alternative. If there were no significant difference in esthetic yield between the two methods, the alternative yielding the greater present value of stumpage returns would be chosen.

The differences in present values between stand models for any given cutting method (table 21) show how inherent stand characteristics affect the capital value of a timber stand.

Esthetics and Economic Choice

The foregoing analysis has presented a wide range of timber yield and financial consequences of simulated timber cutting programs in landscape areas. However, little has been added to our understanding of how to choose among the alternatives when the esthetic yield of the alternatives must also be considered. After a short discussion of some concepts of landscape design applied in a forest management context, a point of view will be presented about decision making when dollar and nondollar yields are considered simultaneously.

Landscaping Concepts and Timber Cutting Alternatives

Principles of modern landscape design have an ancient heritage. However, a recent paper based on research by Twiss and Litton (1966) concisely expresses some of these concepts in the broad setting of natural resource use. These authors state that

> . . . the assumptian is frequently made that "good" scenery results more or less autamatically fram same given practice or land use, such as soil conservation, sustained yield management, ar preservatian.
>
> We contend that optimum visual results cannot be expected to accur spontaneously, but must be actively cansidered and pursued. Values accruing to the public that observes the landscape depend upon an interaction between peaple and the regianal resource base; and good management should be based an analyses of both of these variables.

They offer as a starting point for analysis of the landscaping consequences of resaurce management the four landscape characteristics or "criteria" of: (1) nature, (2) beauty, (3) meaning, and (4) imageability.

With respect to the **nature** criterion, it can be argued that even clearcutting can incorporate "natural" lines of topography in the design of the edges and location af clearcut areas. With forethought, it may be possible to maintain the essential "naturalness" by avoiding straight lines or abrupt changes fram the natural to the man-dominated landscape. This thought can also be interpreted in terms of maintaining a more or less continuous forest crawn caver, either thraugh shelterwood or through lighter partial cuts. Finally, in view of the fact that most landscape management areas may be only ordinary scenery, the emphasis in these cases upon naturalness rather than uniqueness seems especially appropriate.

Even though beauty is a complex and relative characteristic, there are concepts of visual composition — e.g., balance, harmony, unity, contrast, form — which might be applied to the farest landscape. The design and construction of roads, bridges, and campgrounds are particularly amenable to these cancepts. Hawever, timber cutting can also conform ta broad beauty criteria such as harmony and unity by making the cutting "fit" the landscape purpase. If the roadside timber is in an area already known as a "managed" area depending heavily an timber harvest activity, some of the heavier cutting alternatives such as shelterwaod may be accepted readily by the public. Furthermore, a wide belt af vigarous reproductian fallowing harvest cutting in such areas may elicit as much ar more public approval than a narrow screen af towering ald growth which may be very much out of place in terms af the daminant purpose af the general area. On the other hand, same roadside timber stands may be within an area noted for its batanical and ecolagical uniqueness. In this kind af area, cutting must be planned to canform to this uniqueness. Conversion to a talerant type may be appropriate if it "fits" the already apparent ecalogical succession af the area. No cutting, of course, may also be an alternative in same cases. Hawever, this alternative was nat examined in this study.

A particular landscape will have **meaning** thraugh the experience and intuitive appreciation of the beholder. Landscape design pravides a means of capturing this meaning by building it into the landscape. A timber stand may have spiritual meaning to thase who infer supernatural relatianships from such natural objects as trees. In such cases it may be considered appropriate to create a cathedral-like atmosphere with light cuttings in old-grawth timber. On the ather hand, the forest may represent a storehause of economic goods and services which, thraugh careful husbandry, help sustain the "gaad life." Provision of a variety of these settings may provide for a variety of rich experiences. Forethought and creativity will be required ta determine which meaning should be given preference in particular places and which timber cutting practice will serve as the appropriate tool.

Imageability is strangly related to meaning. Twiss and Littan derive two implications from this cancept. In their words:

> First, observers tend ta notice things which already have strang or symbolic meaning for them. Many will be shacked by the sight af bulldazers, slash piles, and tree stumps; but they may be reassured if these are seen as part af a full cycle of harvest and grawth and if it is obviaus that the land is being used with care. It is incumbent an the resource manager ta identify those aspects of his work which are visually striking and meaningful ta observers. With the caming of intensive resource use, he can no langer merely canceal the negative symbals. Now he must positively display mast ar all af the attributes af resource management and development.

The second implication of the concept of imageability is that the composition, depth, scope, and duration of view must all be considered. For example, a traveler will be bored by the endless high vegetation of roadside strips; irritated by fleeting glimpses of vistas that invite extended observation; or stimulated by thoughtful contrasting of scenes.

Again, care in the selection of cutting method will be required to produce the desired image. Shelterwood cutting, for example, might provide maximum depth of visual penetration of the roadside forest and thus permit more of a feeling of being in the forest rather than of exclusion from it by a visually impenetrable wall of closely grown trees.

Choosing Among the Alternatives

Given the dollar and nondollar consequences of the alternative methods of cutting timber in roadside strips or other parts of the forest landscape, the basic question remains: How is the choice among the alternatives to be made? It is obvious that one cannot add together **directly** the dollar and nondollar "returns" from a given alternative. Timber and esthetics, like apples and oranges, simply are not additive, having no common value measure.

However, two approaches are available to the decision maker who must use a set of apples-and-oranges consequences on which to base his decision. These are called here: (1) the simple betterness method and (2) the compensation or trade-off technique.

Simple betterness. — This method relies on the principle that the alternative is selected which results in at least some improvement in some respect over the other alternatives, with no consequent deterioration in any respect relative to the other alternatives. The double-scaled graph of figure 13 can be used to illustrate the method.

The left-hand scale of the graph represents net dollar returns, such as stumpage, from each of five assumed alternatives. The right-hand scale of the graph represents net nondollar returns, such as esthetics, from each of the alternatives. The symbol U has been used to represent these nondollar utilities. The right-hand scale is both undefined (i.e., there are no measurable units) and indeterminate (i.e., no known limit); hence, dashed and broken lines are used. Although cardinal dollar measurements are made on the left-hand scale, only ordinal "better than" elongation of the tips of the bars associated with the alternatives is possible on the right-hand scale. One may thus say that alternative number 3 is somewhat better than alternative 5 with respect to their nondollar utilities, and that alternative 2 is much better than alternative 3. However, in the sense used here, it is not possible to determine the exact amount by which one alternative is better than another on this ordinal scale. It is enough to know — or be able to judge — that one is not at all, somewhat, or much better than another.

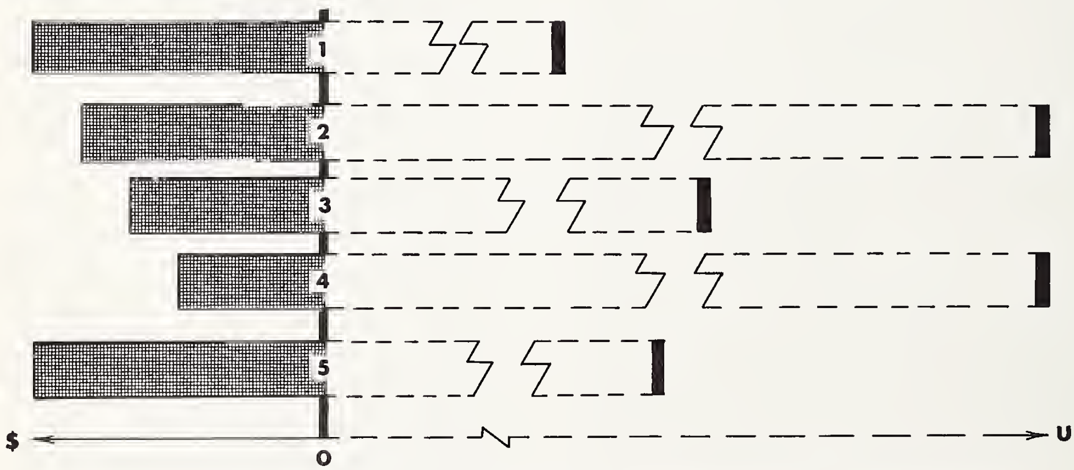

Figure 13.--Simultaneous display of dollar and nondollar (utility) consequences of five hypothetical alternative actions.

An important characteristic of the graph is that the dollar and nondollar portions of the benefits of each alternative cannot be added together. Nevertheless, the graph permits the choice maker to use both kinds of consequences together in comparing alternatives. The choice clearly becomes one among explicit alternative actions and not among alternative values.

The simple betterness principle, illustrated in figure 13, narrows the range of choice to alternatives 2 and 5. Alternative 5 is equivalent to alternative 1 in terms of dollar yield, but superior in nondollar yield. Hence, 5 is superior to 1, and alternative 1 is no longer considered. It is easily seen that alternative 2 is superior in both respects to alternative 3; and, although yielding nondollar returns equal to those of alternative 4, is superior to 4 in terms of dollar returns. Hence, alternative 2 is superior to alternatives 3 and 4. At this point, then, the choice is between alternatives 2 and 5.

At this point, too, the simple betterness method fails us, even though it has served helpfully to narrow the range of choice. Obviously, alternative 5 is superior to alternative 2 in terms of dollar yield and alternative 2 is superior to 5 in terms of nondollar yield. However, there is no objective way to measure the exact difference between the nondollar yields of 2 and 5, and there is no method to determine whether this nondollar difference is equal to, greater than, or less than the difference between the dollar yields of 2 and 5.

When this simple betterness method is applied to a problem like choosing between cutting methods to accomplish a particular purpose, the betterness or nondollar valuation of any specific alternative may change from situation to situation or site to site. In other words, a method which works well in one instance may be less desirable in another. Hence, it is risky to generalize about the ranking of alternatives without reference to the particular situation in which they may be used.

The measures of present values developed in this report can be used to fill in the left-hand side of a graph, such as that shown in figure 13. However, measures of the nondollar yields of the alternatives studied have not been made. It appears possible, nevertheless, for the timber manager to judge the relative nondollar betterness of these alternatives for particular purposes and at least narrow the range of alternatives to be further evaluated. It also appears likely that some choices may be completely resolved by the simple betterness method.

Compensation technique. — The simple betterness procedure outlined above is recommended for resolving choices wherever possible and for at least narrowing the range of choice. However, the choice might become like that between alternatives 2 and 5 in figure 13. In such cases, it is necessary to attempt to overcome the ordinality or "intangibleness" of the right-hand scale. This is done by permitting the choice maker to trade off dollar and nondollar values — or compensate for the loss of one kind of value with added increments of another. Compensation may be accomplished objectively or intuitively. In either case, the degree to which the choice maker's preferences conform to those of others is open to question.

An "objective" method, relying on precedent for valuing nondollar yields in dollar terms, uses "shadow prices." Shadow prices of the nondollar yields of a specific alternative might be estimated as equivalent to the dollar value forgone by using the same alternative in another instance to accomplish the same purpose. For example, a two-cut shelterwood system may have been used successfully to treat a roadside area. Clearcutting the same area would have yielded $400 per acre more in present net worth. Hence, the worth of the difference in nondollar yields between the two-cut shelterwood and clearcutting might be taken as at least $400 per acre. This value is then compared with the difference in dollar value yield between the two alternatives . The problem here is that use of the shadow price **presumes** that the previous decision was a good decision, and that the nondollar yield was **actually** equivalent to the dollar yield given up.

Assume that alternatives 2 and 5 in figure 13 are a two-cut shelterwood and a clearcut, respectively. Assume further that the shadow price of the difference in nondollar yields is $400 per acre in present net worth. Finally, assume that the dollar yield difference, in terms of present net worth, between alternatives 5 and 2 is $200 per acre in a new area being

considered for treatment. In this case, even though use of a two-cut shelterwood would require forgoing $200 per acre of dollar yields (the difference in present net worth between shelterwood cutting and clearcutting in the present hypothetical situation), the $400 per acre shadow price of the difference in nondollar yields between shelterwood cutting and clearcutting more than compensates for the loss.[8]

In this study, no attempt has been made to determine the shadow prices of the alternative cutting methods examined. The study merely outlines the method for obtaining and using such values. Nevertheless, based on the data examined, it would appear that the shadow prices for some cutting methods which may enhance esthetics can be substantial in old-growth Douglas-fir.

The "intuitive" method of compensation simply requires a judgment by the choice maker that the total benefits, however measured, of a chosen method are greater than the similar benefits of any alternative. It is intuitive in the sense that the choice maker relies more on "feel" for the right choice than on more or less mechanical methods, such as the shadow price valuation method employed above. A considerable amount of experience may underlie the intuitive judgment. Although the more objective approach outlined above may appear less arbitrary, it cannot be guaranteed to result in a more correct choice.

Summary

Data and methods for calculating present net worths for several alternative timber cutting practices in a range of old-growth Douglas-fir stand conditions have been presented. These cutting practices have been viewed as possible treatment alternatives in old-growth Douglas-fir where esthetic yield is also important.

There is nothing new about the method for calculating present net worth. The calculations nevertheless make explicit the dollar costs, in terms of present net worths forgone, of choosing one method over others. To the extent that old-growth Douglas-fir stands which are candidates for treatment fit the stand conditions studied, a reasonably good picture of the relative economic desirability of the alternative treatments has been presented. Where the effect of management will be on allowable cut increment rather than on individual stand yield increment, valuation should be on that basis.

However, the decision to be made requires simultaneous consideration of both the dollar and nondollar consequences of the alternative cutting practices. Some discussion of major kinds of esthetic concepts incorporated in landscape design was presented.

Finally, two kinds of choice processes were proposed to the choice maker: (1) the simple betterness method and (2) the compensation technique. Future research might well be directed toward improvements in similar choice processes and the valuation procedures required.

[8] Note that a new shadow price of $200 per acre can be inferred from this last case since the choice of shelterwood cutting required giving up only $200 of present value per acre. The question arises: Which shadow price should be used in future valuations? Presumably, to the extent that the nondollar consequences — and, hence, differences — remain the same from case to case, the highest valued shadow price should be used, remembering the "good decision" presumption previously noted.

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